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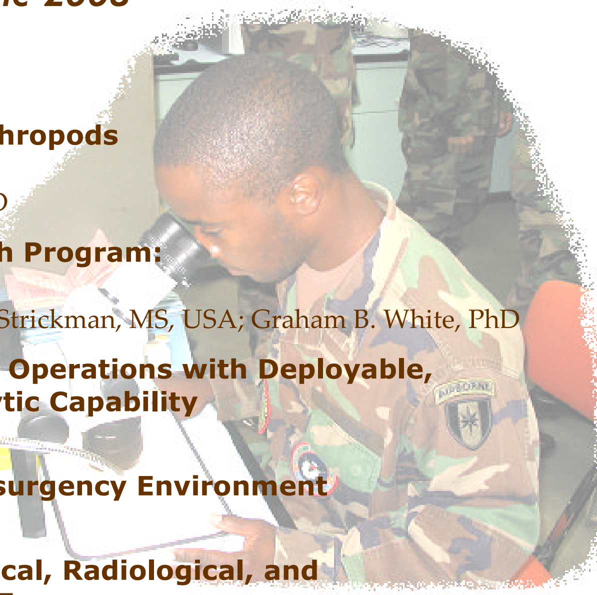

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The Deployed Warfighter Protection Research Program: Finding New Methods to Vanquish Old Foes

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Introduction

The Deployed Warfighter Protection research program (DWFP) is an initiative to develop and validate novel methods to protect United States military deployed abroad from threats posed by disease-carrying insects.[1] Vector-borne diseases such as malaria, dengue, leishmaniasis, and chikungunya are among the most important health risks facing deployed troops. There are no vaccines for many diseases transmitted by biting insects, so methods in insect management and control, as well as personal protection, are the primary tools available to protect troops.[2-5]

During and following World War II, scientists from the US Department of Agriculture (USDA) were regularly funded by the Department of Defense (DoD) to develop new methods and materials for controlling biting insects, particularly those that transmit diseases to humans. This highly successful collaboration produced tools that are still part of our insect-control arsenal today. Examples include:

- Deet (N,N-diethyl-3-methyl-benzamide), the primary ingredient in the majority of insect repellents available today.
- Ultra low volume application of insecticides, a methodology that distributes a limited amount of chemical per acre by optimizing the dispersion and concentration of size-limited droplets, now the standard method used by spray trucks deployed to protect neighborhoods against mosquitoes.
- Permethrin-impregnated fabrics for personal protection against the bites of ticks, mosquitoes, and other blood-feeding flying insects. Permethrin is a synthetic pyrethroid insect repellent that is used to treat uniforms, bed nets, tentage, and other fabrics.

On a global basis, many diseases transmitted by insects are increasing and spreading (eg, chikungunya, dengue, West Nile fever) or remain widespread and prevalent (eg, malaria, leishmaniases, trypanosomiases) despite variable vector control efforts. This situation is demonstrated in Table 1. Also, increasing numbers of species of medically important insects are developing resistance to insecticides commonly used today. For strategic reasons, therefore, there is a critical need in the DoD for the types of products USDA is uniquely able to provide. The DWFP is designed to not only encourage the rapid development of such products, but also to improve the capability of USDA to provide long-term, innovative support to military preventive medicine. In short, it is the intent of the DoD, through the DWFP, to provide funding to the USDA Agricultural Research Service (ARS) to reinvigorate this mutually beneficial working relationship between DoD and USDA, particularly as it pertains to DWFP, as defined in 2 written agreements.[7,8]

Administration and Areas of Emphasis of the Program

The DWFP is administered by the Research Liaison Officer of the Armed Forces Pest Management Board. The program, which was started in Fiscal Year 04, is funded at $5 million per year. It consists of a noncompetitive funding process for USDA ARS-based research, and a competitive grants process open to non-USDA ARS scientists. Up to $3 million per year is given to USDA ARS, specifically to National Program 104, dealing with Veterinary, Urban, and Medical Entomology. The funds are then distributed to various laboratories within the USDA system as described below.

Up to $1.4 million is awarded each year in new competitive grants. The amount available for new

*Detailed information on the DWFP can be found at http://www.afpmb.org/dwfpresearch.htm.

Table 1. Major Global Vector-borne Diseases[6]

Vectors	Diseases	Incidence, Prevalence
Mosquitoes	Malaria	Warm regions—deaths in excess of one million per year
	Lymphatic filariasis	Warm regions—infections in excess of 200 million
	Arboviruses (chikungunya, dengue, Japanese encephalitis, Rift Valley fever, West Nile virus, yellow fever, etc)	Spreading—epidemics increasing
Flies and roaches	Dysentery	Global and repetitive
Sand flies	Leishmaniases	Focal—approximately 6 million infections a year
Fleas	Plague	Widespread—occasional outbreaks
Blackflies	Onchocerciasis (River Blindness)	Africa and Americas: focal—less than 10 million cases
Tsetse	African trypanosomiases (Sleeping Sickness)	Africa: focal—less than 5 million cases
Reduviid bugs	Chagas disease	Americas: 24 million cases across 15 countries
Ticks and mites	Borrelioses, ehrlichias etc	Widespread
Snails	Schistosomiasis	Warm regions—Approximately 200 million cases

starts each year depends on how many projects are carried over from previous years. Grants are awarded for up to $250,000 per year, for up to 3 years. The call for preproposals generally goes out around September. These are then reviewed by a DWFP Technical Committee, consisting of 8 to 10 members, civilian and military, representing the Army, Navy, and Air Force. Based on preproposal reviews, investigators may be asked to submit a full proposal. In November, the DWFP Committee convenes for a 2-day review of the USDA research and to determine which new competitive grants will be awarded. Final competitive award winners are usually notified in December.

The DWFP research portfolio is concentrated in 3 specific areas: novel insecticide chemistries/formulations, application technology, and personal protective systems. The first area includes discovery of new active ingredients, tests of existing insecticides on pests and vectors of public health importance, especially mosquitoes and sand flies, and reformulation of existing insecticides to improve efficacy or delivery.

Involvement of the US Department of Agriculture

The USDA ARS has been a partner in DWFP since 2004, but cooperation between the nation's agricultural research and the military goes back many decades. World War II was a unique moment in this relationship. American forces were faced with the usual disease challenges of warfare, but, for the first time, scientific understanding and industrial capacity combined to offer hope of preventing those diseases caused by vector-borne pathogens. The USDA Bureau of Entomology and Plant Quarantine laboratory in Orlando[9] targeted the flea vectors of plague, the louse vectors of typhus, the chigger vectors of scrub typhus, mosquitoes including vectors of malaria and yellow fever,[10] as well as bedbugs, cockroaches, flies, and ticks.[11] In just a few years, the laboratory refined the uses of DDT* as a control agent for public health pests and of repellent chemicals (ethyl hexanediol, dimethyl phthalate, dimethyl carbate, indalone, and benzyl benzoate) as topical and clothing repellents. Workers at the Beltsville Center invented the insecticidal

*1,1,1-trichloro-2,2-bis(p-chlorophenyl)ethane or Dichloro-diphenyl-trichloroethane

aerosol bomb[12] (precursor of all spray cans) for military use during WWII, and collaborated with the Orlando Lab to invent the repellent deet[13] in 1947.

The USDA continued to collaborate with the military through the 1970s and 1980s, most notably working out the means for permethrin treatment of military uniforms.[14-16] Concentration on military problems slowed, eventually reduced to the development of repellent active ingredients and improved trapping systems. The DWFP effort brought greater focus in 3 ways. First, it provided significant funds ($3 million per year) to the USDA ARS for research. Second, it defined the subject areas of most interest to the military, namely new toxicants for public health pests, new application equipment for pesticides, and new personal protection system. Finally, the DWFP established mechanisms of communication between the military and the USDA ARS that have kept both sides engaged in the conversation on the direction of research required to produce products for the protection of military personnel from arthropods that transmit pathogens.

During the last 3 years we have conceived and executed the concept of a "virtual laboratory" that takes advantage of the core strengths of the USDA ARS at each of the laboratories to establish a smooth flow for development of new vector control products. Chemical discovery proceeds from several strategies that are, for the most part, based on basic science rather than bulk screening. Promising candidates emerge from bioassays, leading to more comprehensive evaluation against target insects. Once we have what we think is a useful chemical, we consider how best to use it against target insects in an integrated pest and disease management program. With those goals in mind, we have in the past approached individual private companies in order to form a partnership for further development. In that case, it is up to the company to formulate the active ingredient. Recently, we have been performing research on formulation, reasoning that a preparation closer to product status may be more attractive for industrial development. We are also working on regulatory issues by funding a position on public health pesticides with IR-4*, the USDA-funded entity that supports registration of pesticides for use on specialty crops.[17]

Some USDA ARS laboratories and investigators have had only a temporary involvement with DWFP, depending mainly on whether the core agricultural mission of their unit effectively synergized the military mission of the funds. Currently, there are 5 laboratories that receive DWFP funding. The following sections discuss some of the work underway in those laboratories.

Invasive Insect Biocontrol and Behavior Laboratory

The Invasive Insect Biocontrol and Behavior Laboratory in Beltsville, Maryland, is the laboratory that first patented deet[13] the dominant active ingredient in American insect repellents. It continues to be well-equipped to perform any level of synthetic and analytical chemistry, an obvious advantage for a laboratory attempting to discover new toxicants and repellents. Chauhan and colleagues[18] have been involved in the discovery of promising new repellent active ingredients, mosquito larvicides, and exciting new insecticidal chemistries. He takes advantage of a small *Aedes aegypti* colony on site and performs simple, screening bioassays to guide his work. Another research team is at the cutting edge of research on how mosquitoes detect hosts.[19] Using molecular biology and electrophysiology, they will develop tools that dissect biting behavior into its component, physiological parts. Combined with the synthetic chemistry of the laboratory, this work will provide very precise pathways for discovering entirely new behavior-altering chemicals. Potential products could be chemicals that selectively repel infected mosquitoes, chemicals that induce mosquitoes to bite nonhuman hosts, and powerful attractants that could be combined with toxicants.

Mosquito and Fly Research Unit

Scientists at the Mosquito and Fly Research Unit (MFRU) in Gainesville, Florida, are experts on many aspects of the biology and control of mosquitoes and flies. Their work includes the following:

*Interregional Research Project No 4 (IR-4), the Minor Crop Pest Management Program, is the principal public effort supporting the registration of crop protection products and biological pest control agents for approximately $40 billion minor crop industry. Source: USDA Cooperative State Research, Education, and Extension Service, http://www.csrees.usda.gov/nea/pest/in_focus/ipm_if_minor.html

- Toxicant discovery by Pridgeon et al[20] includes tests of registered toxicants that have not yet been applied for public health pests. They also work with industry to explore the effectiveness of new compounds that have not been used as insecticides. Promising chemicals have also been extracted from native plants.
- Pridgeon and associates[21] have invented an entirely new class of "molecular pesticides" that promise to combine great safety, flexibility, and specificity.[22,23]
- Bernier and colleagues have extended fundamental work to the production of inhibitors for mosquitoes (patent pending) and powerful attractants for flies[24] and mosquitoes.[25] Collaborators at the University of Florida are using computational chemistry (QSAR/QSPR*) to reanalyze pesticide bioassay data generated over 50 years at the Orlando and Gainesville laboratories, resulting in synthesis of repellents with 3-fold longer repellency than deet.[26]
- Researchers Cooperband and Allen[27] have also explored the effects of sublethal dosages of pesticides on mosquito behavior using quantitative interpretation of videos, extending our knowledge of how best to apply residual insecticides.
- Research is underway on fly control, including trapping and toxicants, at field sites in the United States and middle eastern locations.
- The Center for Medical, Agricultural, and Veterinary Entomology, which includes the MFRU, has been very active in developing field tests sites, including Thailand; Kenya; Camp Blanding, Florida; and the Coachella Valley, California. The MFRU works closely with the Navy Entomology Center of Excellence at the US Naval Air Station, Jacksonville, Florida, especially for field testing and evaluation of application equipment.

Biological Control of Pests Research Unit

At the Biological Control of Pests Research Unit (BCPRU) in Stoneville, Mississippi, Lyn and Streett[28] collaborate with scientists at the MFRU and industry to develop formulations of public health pesticides. Also, the BCPRU has facilities for pilot production of biopesticides.

*Quantitative structure-activity relationship/quantitative structure-property relationship

Natural Products Utilization Research Unit

The Natural Products Utilization Research Unit in Oxford, Mississippi, has a history of working in partnership with the University of Mississippi School of Pharmacy on the discovery of natural sources of bioactive compounds. The unit goes beyond simple extracts to complex analysis of families of chemicals and optimization through synthesis of series of compounds. Thanks to DWFP funding, USDA was able to leverage the effort by transferring funds to the University of Mississippi for insecticide development. Cantrell and colleagues[29,30] have already been involved in discovery and patent of repellents and toxicants. The products of their research will be screened on site using a new and very simple bioassay developed by Becnel and Pridgeon[31] at the MFRU. Promising candidates will be evaluated in more detail by the MFRU.

Areawide Pest Management Research Unit

Hoffmann and associates[32,33] at the Areawide Pest Management Research Unit (APMRU) in College Station, Texas, have worked closely with the MFRU and the Navy Entomology Center of Excellence to systematically evaluate the droplet spectra of a wide range of application equipment. The data have already informed the military on the best equipment for its purposes. Also, Nachman's[34] completed work on neuropeptides of public health pests, including mosquitoes, ticks, and flies, has established an entirely new potential mechanism for insecticidal mode of action.

COMPETITIVE AWARD HIGHLIGHTS

Publicly posted on the federal government's website† announcing grant availability, DWFP requests for preproposals have yielded an average of 38 submissions annually, from academics, military entomologists, industry, and others around the world. More than one-third of these have been invited to prepare full proposals, from which 34 projects, shown in Table 2, have been selected for grant funding during the first 5 years of the program. The range of topics and the quality of many proposals have been impressive. Indeed, many of the intended products could find wider applications for public health and veterinary pest control. So far, the smallest grant value was $22,552 over 2 years, while some grants have

† http://www.grants.gov/

Table 2. Deployed Warfighter Protection Research Program Competitive Project Grants

Award Recipient	Purpose	Org*	Highlights
2004 (n=8)			
CDR Claborn (Dr Walker)	Sprayer diesel conversion	M	2 prototypes & NSN†
LTC Coleman	Sand Fly control--Iraq	M	Improved field operations
LCDR Hoffman	Mosquito control with UAV‡	M	Passed to USAF
Prof Phil Koehler	Filth & Biting Fly control	A	1 NSN† & 2 deployed citations
Dr Bob Peterson	Comparative risk analyses	A	Publications & public appreciation
Dr Steve Presley	Hollow fiber impregnated fabric	A	Novel technology
Dr Bill Reifenrath	Repellent synergy	D	Cancelled
Dr Ed Rowton	Sand Fly control--laboratory	M	Essential collaborations
2005 (n=7)			
Prof Chas Apperson	Dengue vector ovitrap	A	Duty under instruction student
Prof Lane Foil	Targeted sand fly control	A	WRAIR§ collaboration
LT Haagsma	Mosquito control with UAV‡	M	Passed to USDA ARS APMRU
Dr Que Lan	Novel mosquito insect growth regulator	A	Product licensed
Dr Mike Scharf	Low molecular weight insecticides	A	Industry support
LT Stancil (LCDR Florin)	Dengue vector larval control	M	EPA¶ registration in preparation
Prof Alon Warburg	Sand Fly control military camps	A	WRAIR§ collaboration
2006 (n=6)			
Bruce Dorendorf	Diesel backpack	D	NECE** collaboration
Bruce Dorendorf	Ultra low volume nozzle	D	NECE** collaboration
Dave Malone	New ultra low volume adulticide etofenprox	D	EPA¶ registration in progress
Dr Phil Kaufman	Novel compounds	A	Duty under instruction student
Dr Bob Peterson	Comparative risk analyses	A	Strategic appreciation
Dr Gaby Zollner	Novel vapor repellent	M	Delayed
2007 (n=3)			
Dr Ed Rowton	Sand Fly control—WRAIR§ laboratory	M	Essential collaborations
MAJ Richardson	Sand Fly insectary, USAMRU-K††	M	Pioneering service
Dr Dolan & Dr McAllister	Natural product pesticides	G	CDC-NCZVED‡‡ collaborations
2008 (n=10)			
Bruce Dorendorf	Ultra low volume backpack diesel system	D	
Prof Lane Foil	Sand Fly larval control	A	
MAJ Stephen Frances	Australia field repellent fabrics	M	
Philipp Kirsch	Adulticides targeting Sand Flies	D	
Prof Phil Koehler	Military protections vs Filth Flies	A	
Richard Poche	Host-target insecticides vs Sand Flies	D	
LT Richardson	Novel tools & strategies vs *Ae.aegypti*	M	
Prof Masoud Salyani	Spray methods vs Sand Flies	A	
Prof Alon Warburg	Phlebotomine control	A	
Dr Mike Willis	Formulate UW4015 larvicide	D	

*Type of organization:
A – Academia (n=14) D – Industry (n=8)
M – Military (n=11) G – Other government (n=1)

†National Stock Number
‡Unmanned aerial vehicle
§Walter Reed Army Institute of Research
¶US Environmental Protection Agency
**Navy Entomology Center of Excellence
††US Army Medical Research Unit, Kenya
‡‡US Centers for Disease Control and Prevention–National Center for Zoonotic, Vector-Borne, and Enteric Diseases

exceeded $200,000 per year for 3 years. Awardees are encouraged to seek patents and find licensees for their products, several of which are already nearing commercialization.

For example, in 2005 a grant was awarded to ADAPCO (Sanford, Florida) to develop etofenprox[35] for use as mosquito ultra low volume (ULV) adulticide. This chemical, a nonester pyrethroid manufactured by the Mitsui Group in Japan and licensed to Central Life Sciences (Schaumburg, Illinois) for US registration for public health applications, is far less toxic to humans, animals, and birds than most other insecticides currently used for mosquito control.[36] It is expected to receive EPA approval for marketing this year.

Although the DWFP program prioritizes the discovery and development of agents for use against blood-feeding adult mosquitoes and biting flies that would afflict deployed military personnel, some research grants have been awarded for development of chemicals with new modes of action against mosquito developmental stages in water. At the University of Wisconsin, Madison, Lan and colleagues[37-41] had the idea to block sterol carrier proteins that are metabolically essential for the nutrition and growth of mosquito larvae. After screening tens of thousands of candidate compounds, they discovered several with the power to block mosquito sterols, effectively serving as growth inhibitors. The most appropriate compound has been licensed by a commercial company where it is being formulated for applied use. Both phases of the work have been supported by DWFP grants.

Figure 1. Yamaha RMax unmanned aerial vehicle fitted with ULV spray nozzles (top) and with twin hopper (bottom) for application of granular larvicide to control mosquitoes.

Among DWFP grants awarded to scientifically qualified military officers, the first was for adapting an unmanned aerial vehicle, shown in Figure 1, to carry application equipment for delivery of larvicidal granules or ULV adulticide. This project originated with the Disease Vector Ecology and Control Center (now the Navy Entomology Center of Excellence) at the Jacksonville Naval Air Station, where capabilities were demonstrated, then adopted by the USAF Aerial Spray Unit* at Youngstown, Ohio. To further develop this application technology with an unmanned aerial vehicle platform made in the United States, the project has been transferred to the Application Technology Laboratory of the USDA ARS at the APMRU. This relay of progressive research and development steps has been facilitated by DWFP funds and objectives to meet one of the strategic DoD goals of fielding unmanned vehicles.

Also by collaboration with the Navy Entomology Center of Excellence, a series of DWFP grants have enabled Dorendorf Advanced Technologies, Inc (Winnebago, Minnesota) to design and build new sprayers using military fuels instead of gasoline. The first backpack system, shown in Figure 2, operates almost silently with compressed air from cylinders charged by a diesel-fuelled compressor which also drives a truck-mounted ULV sprayer, the Terminator™. In addition to the strategic advantages of silent spraying, a unique ULV nozzle is being created for the backpack system. Altogether, this

*See related article on page 54.

purpose-built, diesel-fuelled spray equipment will allow troops to be deployed with battlefield-ready spray equipment for vector control.

Figure 2. The first backpack ULV sprayer system developed under DWFP grants operates almost silently with compressed air from cylinders.

From diverse proposals for better insect repellency of fabrics to protect military personnel, one DWFP grant was awarded to researchers at the Institute of Environmental and Human Health, Texas Tech University, Lubbock, Texas. That ingenious project developed a new type of permethrin-impregnated hollow fiber capable of being integrated with many textiles. This durable microcapillary can serve as a convenient carrier fiber for weaving the repellent and insecticidal powers of permethrin into any fabrics used for making clothes, curtains, tents, and other protective layers.*

Two DWFP projects have employed pyriproxyfen, the most powerful insect growth regulator (IGR), against dengue vector mosquitoes. In the Peruvian Amazon community at Iquitos, Stancil[42] (Naval Medical Research Center Detachment, Peru) received a grant to optimize strategies for preventing the breeding of *Aedes aegypti* mosquitoes in containers of water. The project ran for 3 years, and involved collaboration with Peruvian scientists and researchers from the University of California and Rothamsted Research, United Kingdom. In addition to simply stopping the breeding of mosquitoes in treated habitats, effective quantities of pyriproxyfen IGR are transferred from one container to another by mosquito females as they go from site to site laying their eggs, thus impacting more habitats than were treated directly. Mosquito population suppression across whole suburbs of the city has effectively prevented dengue transmission without the need to spray adulticides. Building on that achievement, researchers at the Armed Forces Research Institute of Medical Sciences, Bangkok,[43] in conjunction with local military personnel in Thailand, are now evaluating several devices treated with pyriproxyfen IGR for protecting military camps against *Aedes aegypti* and the arboviruses transmitted by this widespread domestic mosquito (see Table 1).

Figure 3. *Phlebotomus* sand fly (Photo courtesy of Ed Rowton, PhD)

The biggest emphasis of DWFP projects has been to find ways to combat *Phlebotomus* sand flies (Figure 3) which are problematic in many parts of the Middle East. These small hairy flies transmit *Leishmania* parasites that cause disfiguring sores (Figure 4) which fester for many months and require long-term medication. Some forms of the infection go to the liver and can be fatal. More than a thousand US personnel have contracted leishmaniasis during ongoing Operations Enduring Freedom and Iraqi Freedom.[44] Unfortunately, the types of insecticide sprays that normally control mosquitoes are generally ineffective against sand flies. To address this threat, DWFP grants were channeled, by competitive award, via the Entomology Division at the Walter Reed Army Institute of Research to facilitate intensive field studies of sand fly behavior and control. Although a series of research papers by Coleman, Burkett, and colleagues[45-47] have resulted, the sand fly biting problem has not been resolved. Consequently, efforts to understand how to improve the delivery of more effective insecticidal sprays are being reemphasized. Also, Warburg and colleagues[48] at the Kuvin Center of the Hadassah Medical School, Jerusalem, received a DWFP grant to develop measures to protect outposts against sand flies. These projects have revealed that sand flies often emerge from the soil beneath tents and camps. In an effort to prevent sand flies breeding in rodent burrows, the Genesis Company (Wellington, Colorado) won an award for producing insecticidal baits that would pass through specific rodent reservoir hosts of leishmaniasis to prevent breeding of sand fly larvae in their burrows. This approach is being developed with other feed-through treatments by Mascari et al[49-51] at Louisiana

*Project results unpublished to date

Figure 4. Examples of dermal leishmaniasis contracted in Iraq during Operation Iraqi Freedom. Note in the top photo that the area of the arm covered by the shirt sleeve is free of bites, demonstrating the value of simple measures in the prevention of insect bites.
(Photos courtesy of COL Russell Coleman, MS, USA)

State University for field testing against sand flies in Turkey.

Control of filth flies and house flies is best achieved by good sanitation, but this cannot always be ensured in deployment situations. One competitive DWFP award enabled Koehler[52] and military students in the Urban Entomology Unit of the Department of Entomology and Nematology at the University of Florida, Gainesville, to optimize some old countermeasures for fly control. For example, one student evaluated pesticides for residual treatments of various types of string and rope on which flies like to rest. He determined which combination of insecticide and string fiber would be most effective for use against flies in tented camps. Another student continues this line of experimentation by devising ways to drape loops of treated string over attractant traps to which flies are lured and killed. These masters level graduate students were supported by the US Navy's Medical Service Corps Inservice Procurement Program.[53] Another development from Koehler's team, invisible imidacloprid paint bait with attractant for killing flies quickly, was the first DWFP product to receive a National Stock Number from the Armed Forces Pest Management Board.

As the DWFP competitive grants program has grown, awardees have included entomologists at the US Centers for Disease Control, Division of Vector-Borne and Zoonotic Diseases, for development of natural pesticides extracted from agricultural waste. Other plant products that have insect repellent properties are under evaluation for insecticidal potency against flies, mosquitoes, and sand flies, while Scharf and Song[54,55] are exploring low molecular weight compounds that could serve as volatile repellents and insecticides for potential limitation of biting insects over a wide area.

Although the public perception of pesticides can be unfavorable, the facts are that the use of pesticides can be extremely effective against all sorts of pests and disease vectors. In an effort to investigate this dichotomy, one of the most original lines of inquiry funded by DWFP competitive grants has allowed Peterson and colleagues[56-61] at Montana State University, Bozeman, to undertake comparative risk analyses of the impact of pesticides. For a series of model scenarios involving vector-borne diseases such as malaria, West Nile fever, and plague, they carefully quantified the likely benefits of vector control by means of appropriate insecticide applications, versus possible disadvantages to the health of people and environmental impact. One particular study by Macedo et al[62] weighed the potential health benefits of vector control against the adverse consequences of likely exposure of deployed military personnel to pesticides used on clothing and bed nets, and sprayed around the camp. In all cases, the risk to humans was found to be minimal compared with the health benefits of avoiding vector-borne diseases.

Upgrading Defense against Diseases Transmitted by Insect Bites

While many useful products from DWFP research are already on the way towards production and supply for the public as well as deployed troops, the examples described above are far from sufficient to cover all our needs. Apart from combating mosquitoes and the various types of flies that transmit debilitating

infections such as malaria, leishmaniasis, dengue, and other arboviruses, there are many other noxious types of biting insects (bedbugs, fleas, lice, etc) and other arthropods (ticks, mites, scorpions, etc) that merit our concern. With nearly 5 years of progress in the DWFP program, however, our focus remains on the most dangerous flying vectors, particularly certain species of mosquitoes and sand flies. That focus is necessary until we have greatly improved methods and materials to protect our forces deployed to forward situations in all regions of the world from the threats of inconspicuous insect foes. This will allow those forces to more effectively deal with the challenges presented by the more obvious human enemies.

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